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Combined Biogas and Bioethanol Production in Organic Farming

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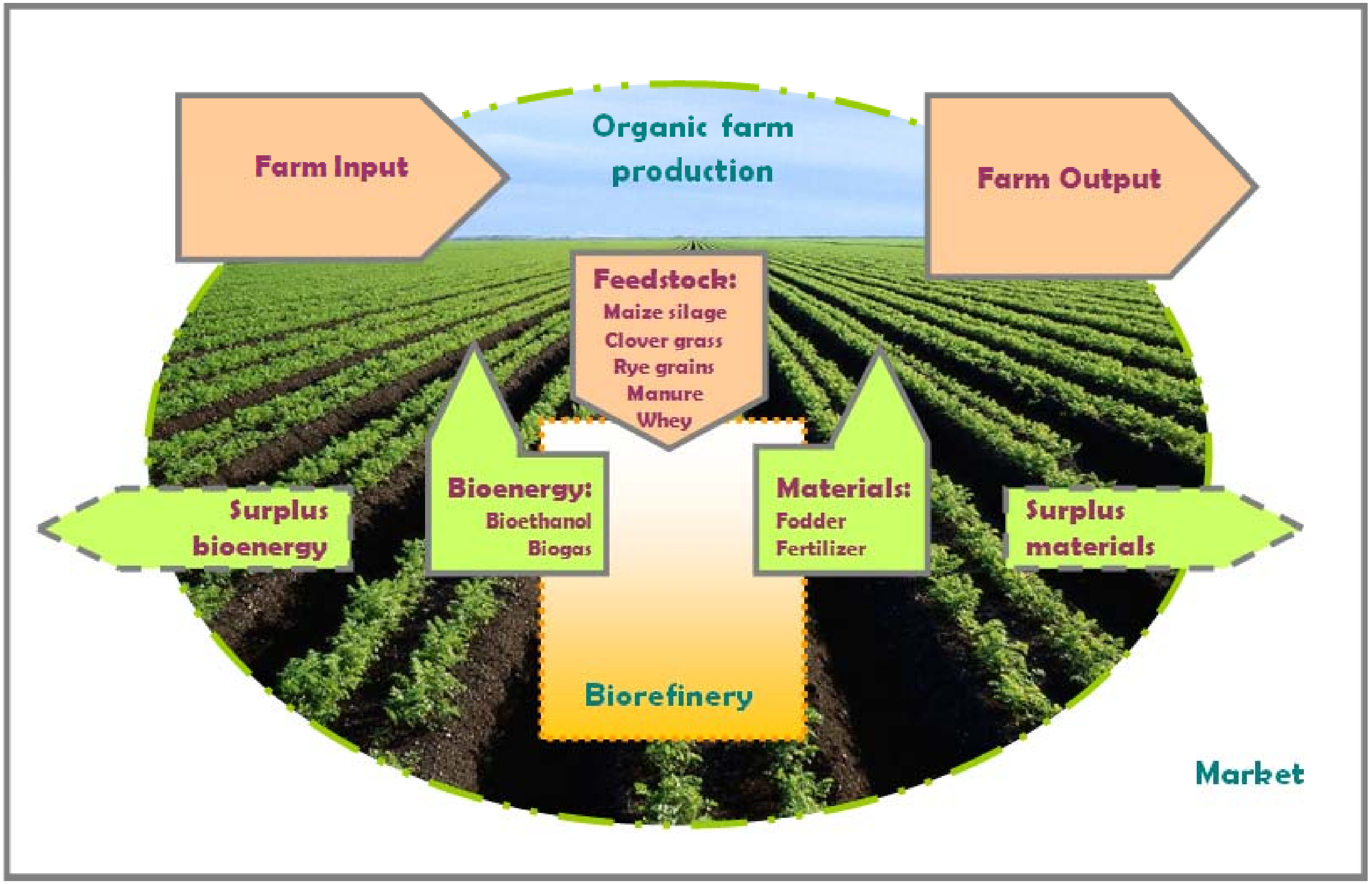
Introduction - BioConcens



http://www.bioconcens.elr.dk/uk/

Production of bioenergy and animal feed

Aim: Convert animal manure, energy crops and agricultural residuals and agro-industrial by-products to biogas, bioethanol and fodder protein

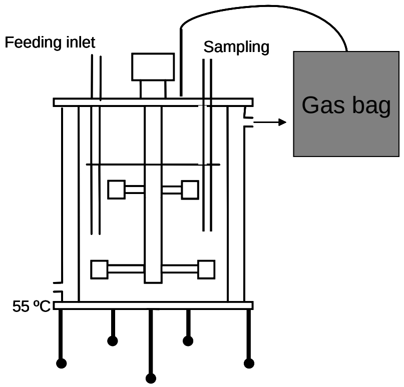
Hypothesis: It is possible to use the organic residuals in organic agricultural (OA) for energy production without diminish the necessary amount of carbon and nutrients that should be recycled to the soil in OA.

Tested biomasses

- Clover grass (fresh and silage)
- Maize straw (fresh and silage)
- Grass from meadows
- Rye straw
- Vetch straw
- Whey
- Cattle manure

Experimental setup - Biogas

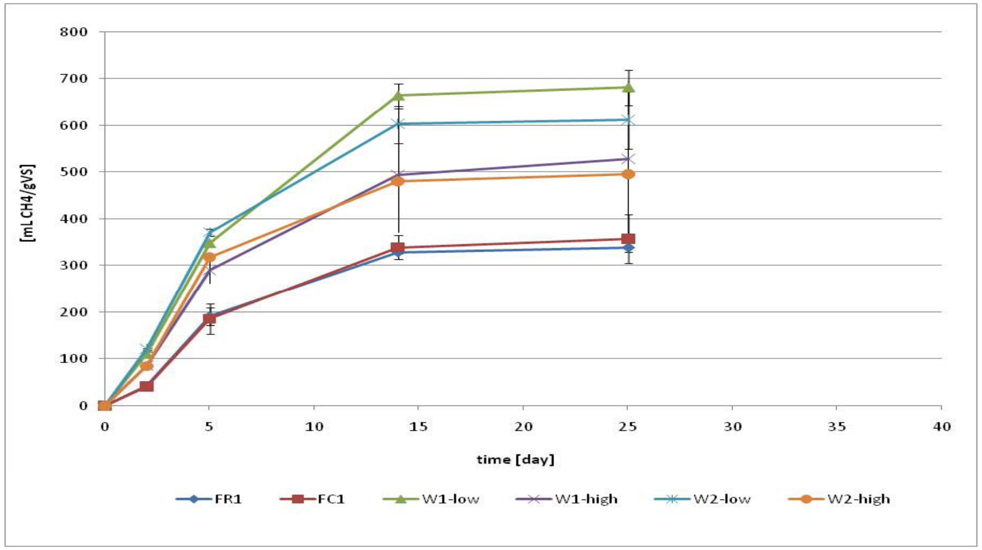
- Batch fermentations trials:
  - each biomass was fermented in triplicate in different concentrations (from 0.5% to 3.3%)



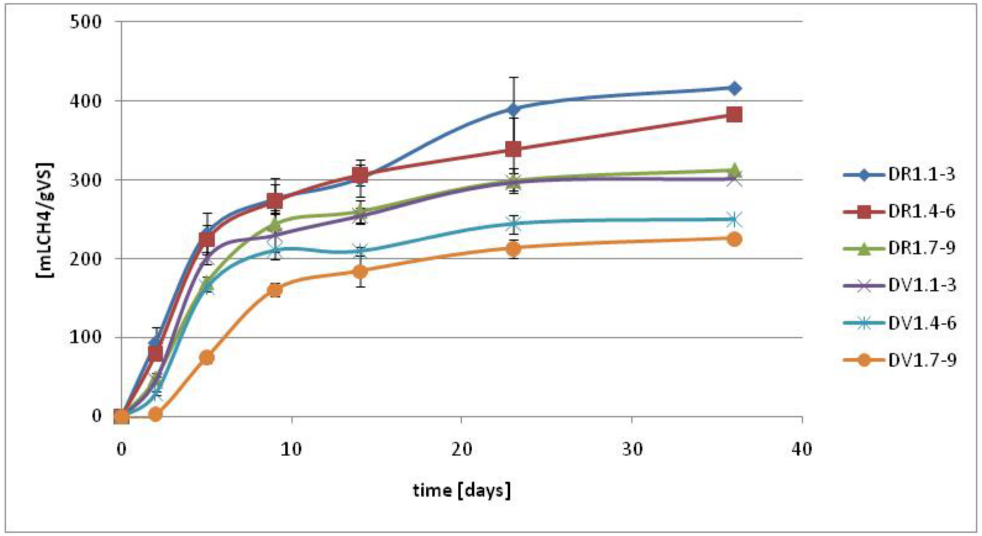
Reactor experiments –

- 50ºC and HRT of 19 days
- Manure and agricultural residuals

Results – biogas potentials



Methane production from fresh rye (FR), fresh clover (FC) and two types of whey (W)



Methane production from dry vetch (DV) and dry rye (DR) at different substrate concentrations:

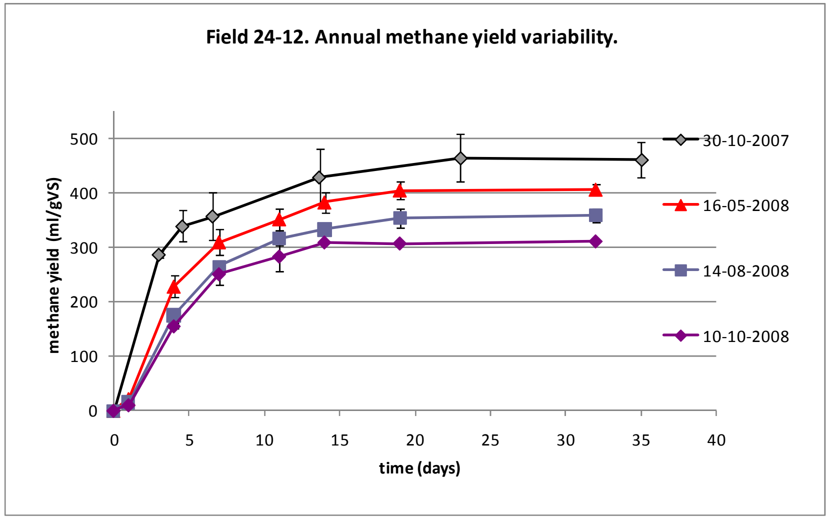
samples 1-3, 4-6 and 7-9 in concentrations 0.5, 1.0, and 2.0 gVS/100g, respectively.

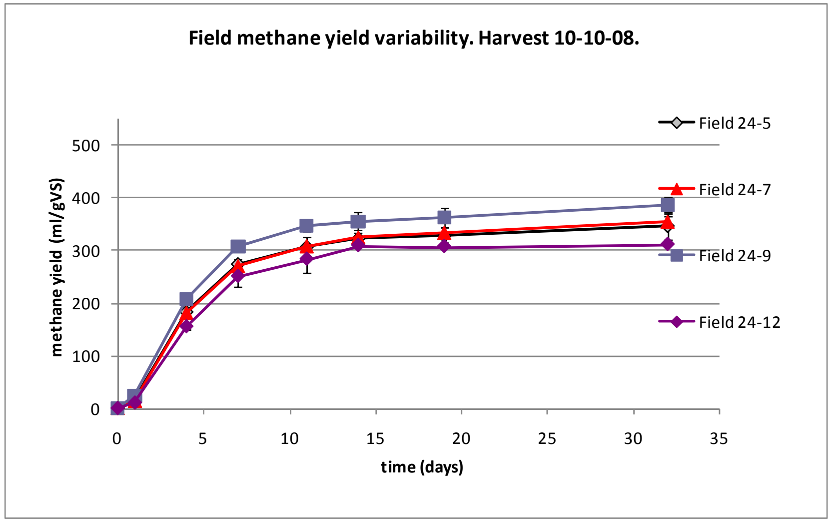
Methane potentials of clover grass and clover grass silage

Field	Harvested
24-5	10-10-08
24-7	10-10-08
24-9	10-10-08
24-12	30-10-07
24-12	16-05-08
24-12	14-08-08
24-12	10-08-08

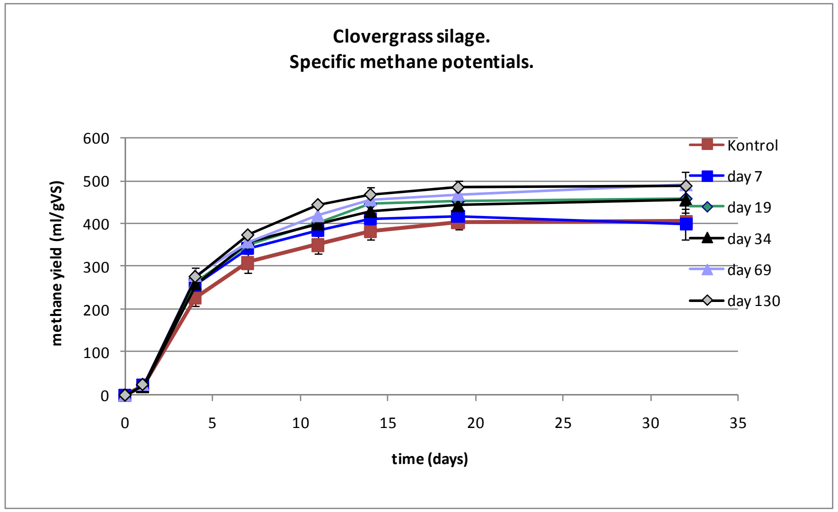
Field 24-12	Silage time days
Control	0
1	7
2	19
3	34
4	69
5	130

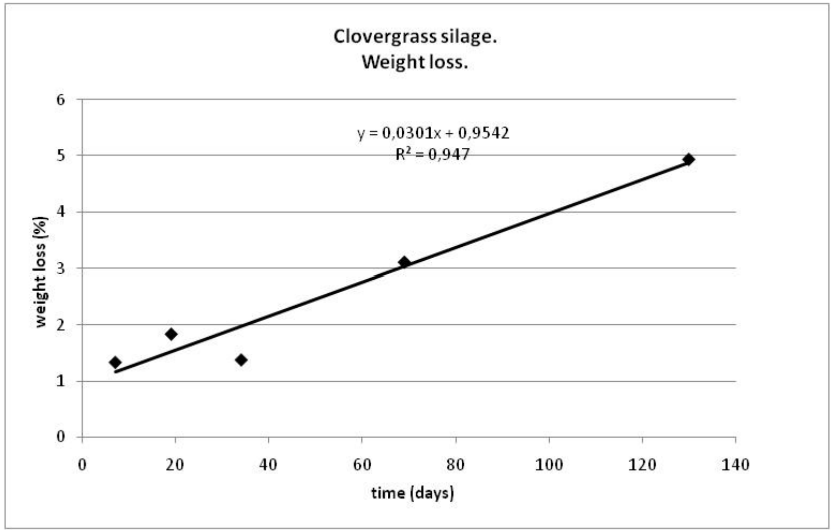
Clover grass. Methane potentials – batch experiments

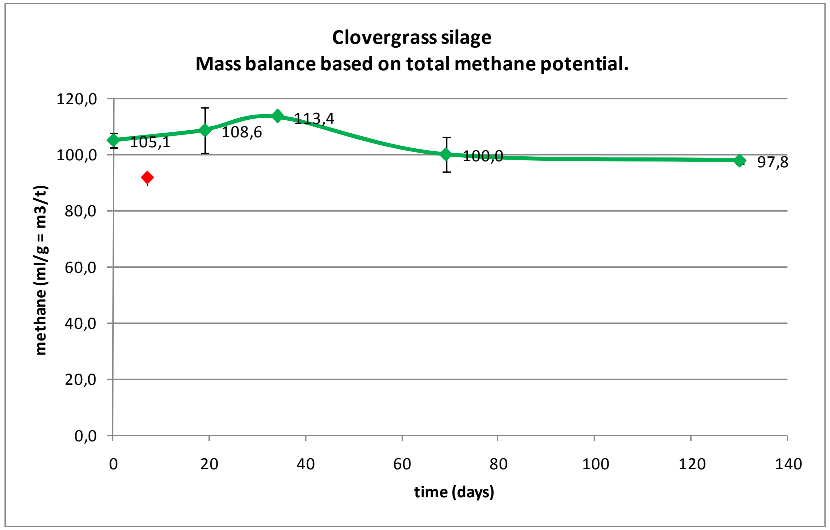




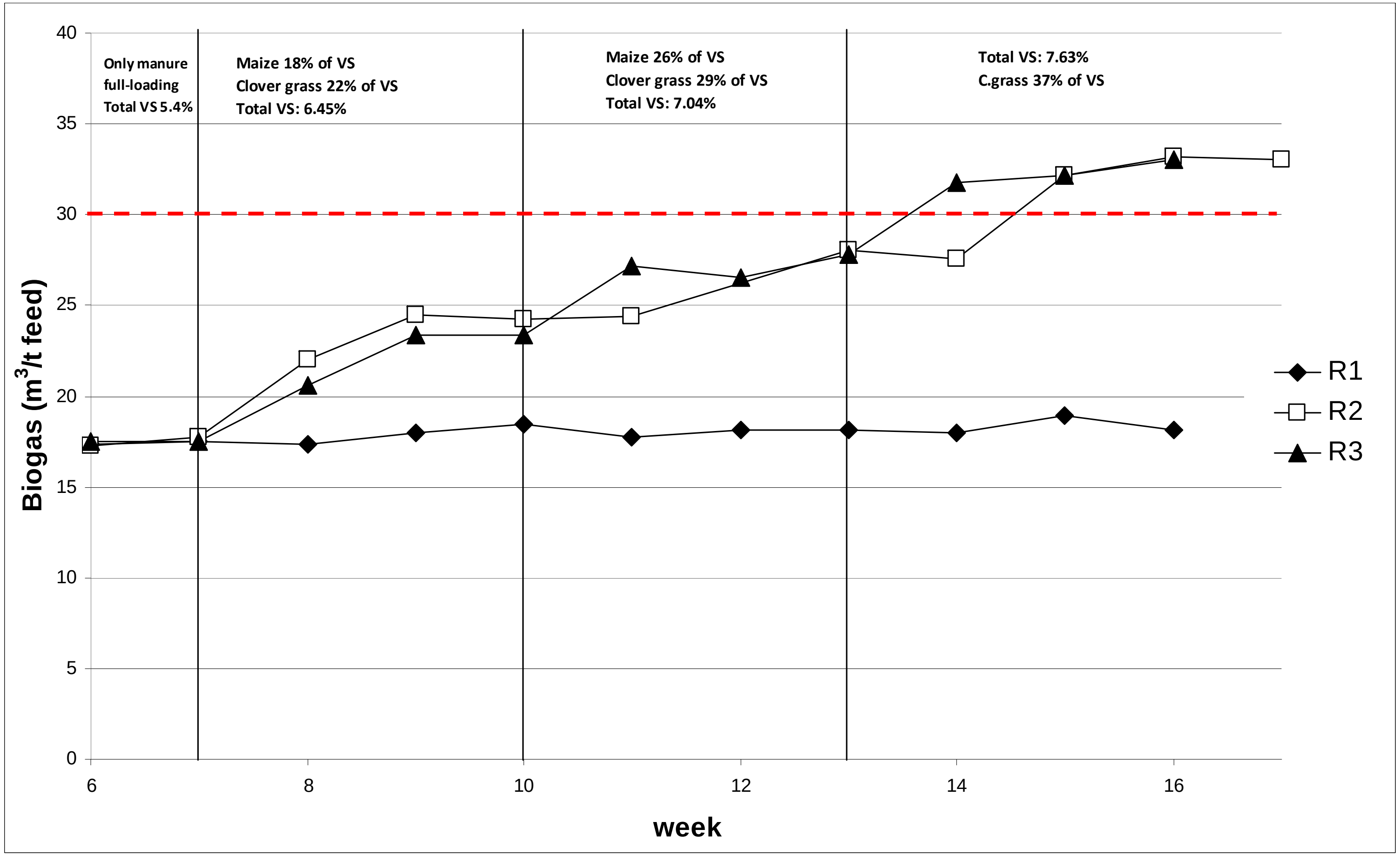
Clover grass silage. Methane potentials – batch experiments







Reactor experiments

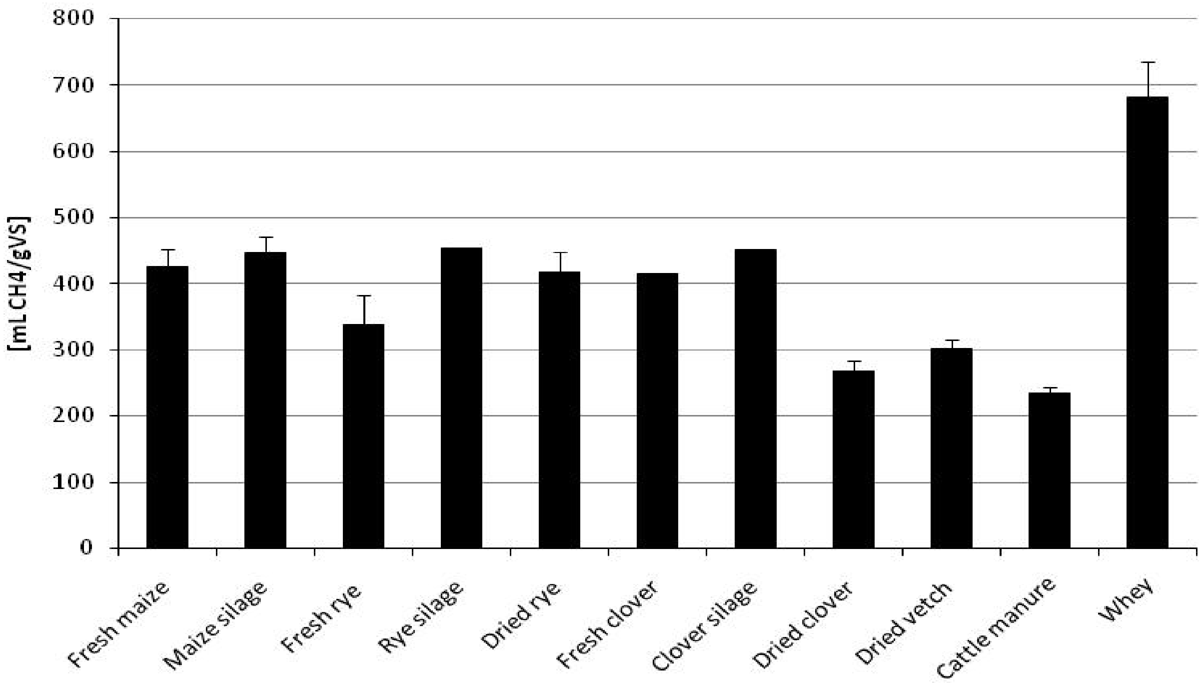


R1: manure, R2: manure + maize, R3: manure + clovergrass

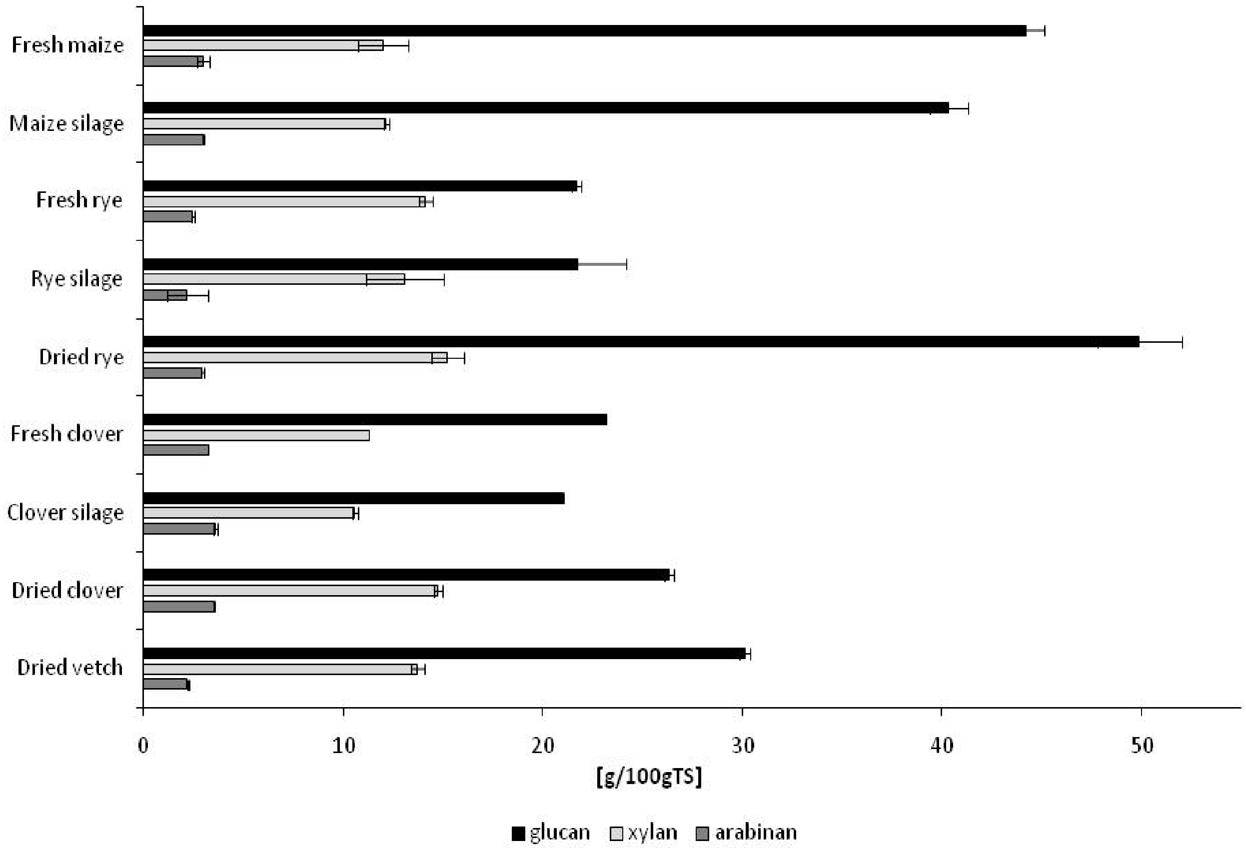
Methane yields

	Reactor yield ml/g VS	Batch potential ml/g VS	
Manure	208	235	Std. dev.
Maize 17.5% VS	327	427	26,0
Maize 25.8% VS	335	427	26,0
Maize 33.0% VS	380	427	26,0
Clover-grass 22.4% of VS	294	406	9,9
Clover-grass 28.9% of VS	328	406	9,9
Clover-grass 36.8% of VS	367	406	9,9

Summery - Biogas

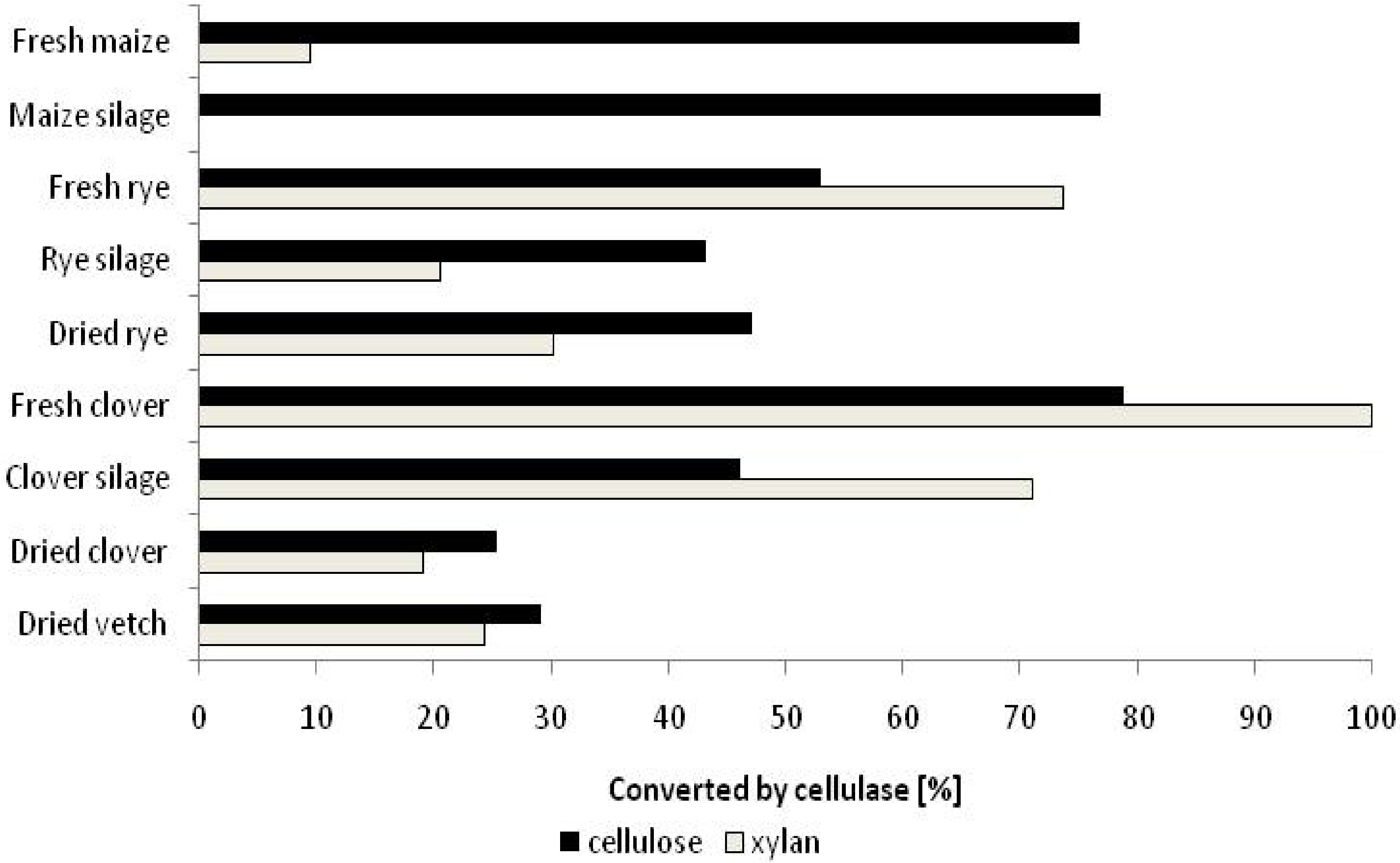


Results – ethanol potential was expressed as an amount of glucose



Composition of the raw materials

The sugars yield after enzymatic hydrolysis



Ethanol production from treated/non-treated maize silage

In order to check if it is necessary to pre-treat/sterilize/pasteurize maize silage, SSF was performed with:

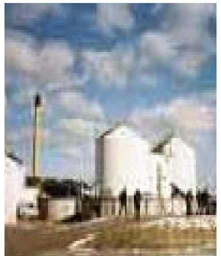
- raw maize silage
- maize silage pasteurized for 4 hours at 70ºC
- hydro-thermo-treated for 10 minutes at 190ºC

The experiments were carried out with two types C-6 fermenting microorganisms:

-***Saccharomyces cerevisae* at 32ºC**

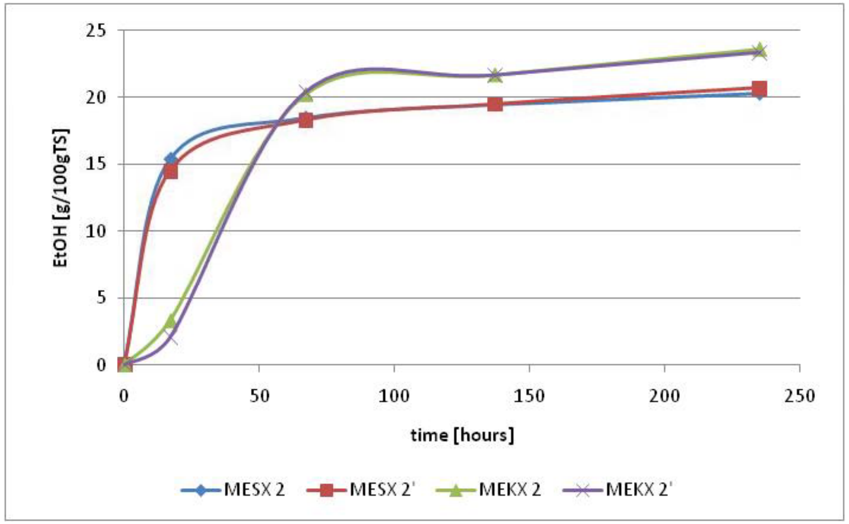
-**and with thermotolerant yeast, *Kluvyromyces marxianus*, at 40ºC**

Ethanol production from treated/non-treated maize silage

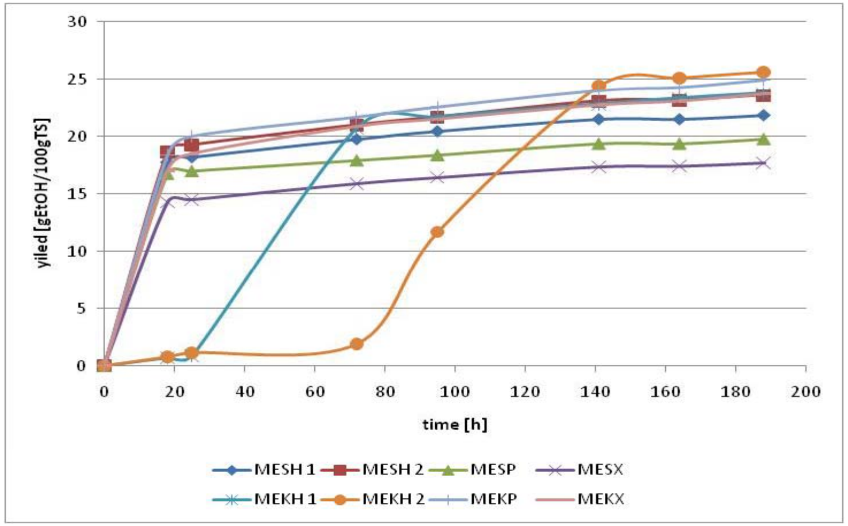



Ethanol production from non-treated maize silage

(M – maize; E – ensilaged;
S – S.cerevisae; K - K.marxianus;
X – non-treated; amylase+cellulase,
' – only cellulase enzymes)



Production of ethanol during SSF of maize silage pretreated at different conditions
(M – maize; E – ensilaged;
S – *S.cerevisae*; K - *K.marxianus*;
H – hydrothermal treatment (190°C, 10 min); P – pasteurized (70°C, 4h);
X – non-treated)



Summery- Bioethanol

Crop	Practical methane yield [mLCH4/gTS]	Practical methane yield [kJ/100gTS]	Theoretical ethanol yield [gEtOH/100gTS]	Theoretical ethanol yield [kJ/100gTS]
Fresh maize (the whole crop)	407 ± 25	1619 ± 99	25.1 ± 0.5	744 ± 15
Maize silage (the whole crop)	426 ± 22	1694 ± 88	22.8 ± 0.5	678 ± 16
Fresh rye (the whole crop)	316 ± 40	1258 ± 160	12.3 ± 0.1	365 ± 4
Rye silage (the whole crop)	422 ± 9	1680 ± 36	12.3 ± 1.3	395 ± 40
Dried rye (the whole crop)	402 ± 31	1601 ± 122	28.3 ± 1.2	839 ± 36
Fresh clover (the whole crop)	375 ± ND	1493 ± ND	13.1 ± ND	390 ± ND
Clover silage (the whole crop)	400 ± ND	1592 ± ND	11.1 ± 0.4	330 ± 1
Dried clover (the whole crop)	245 ± 12	977 ± 49	14.9 ± 0.1	442 ± 4
Dried vetch (the whole crop)	279 ± 13	1111 ± 50	17.1 ± 0.2	507 ± 5
Cattle manure	174 ± 6	51 ± 2 [kJ/100mL]	-	-
Whey	625 ± 48	149 ± 12 [kJ/100mL]	~2.4 g/100mL	~138.8 kJ/100mL

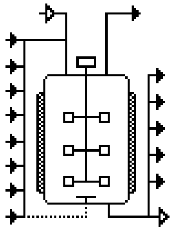
HHV_{CH4}=55.5 kJ/g=39.8 kJ/dm^3
HHV_{EtOH}=29.7 kJ/g

Combined biogas and fodder/bioethanol production

Biomasses

Processing

Products

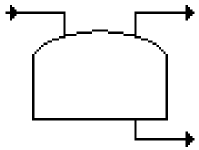


P-1 / V-101

Stoich. Fermentation

Ethanol

Protein feed/ fertilizer



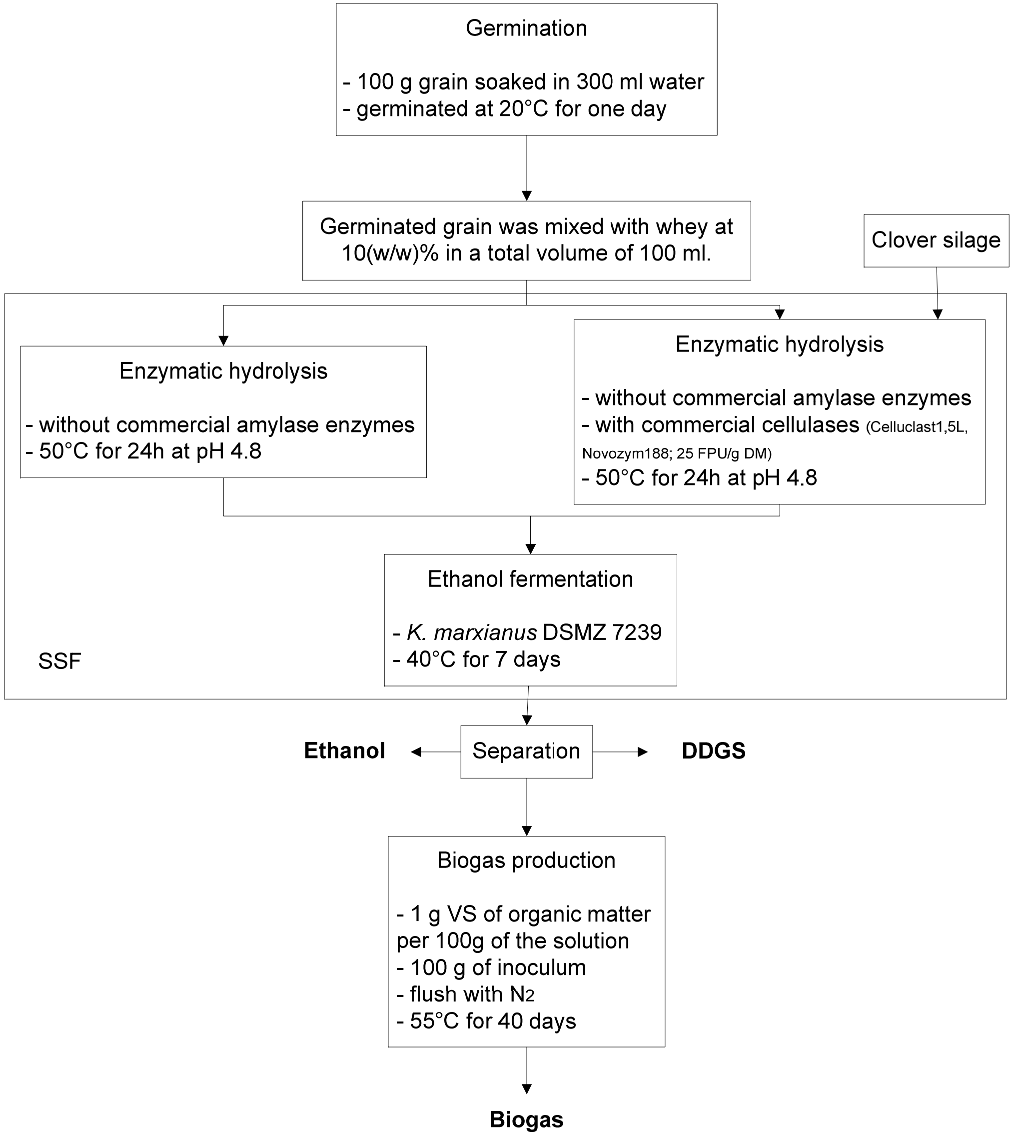
P-15 / AD-101

Anaerobic Digestion

Biogas

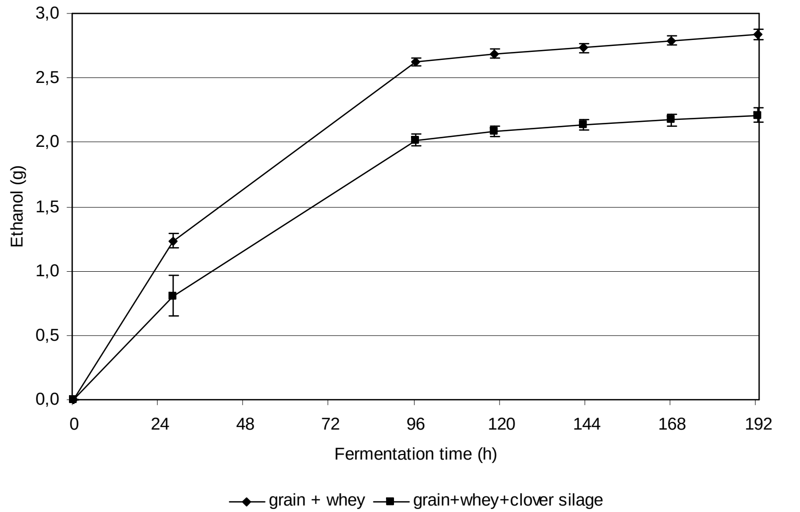
Fertilizer

Combined biogas, bioethanol and fodder production from rye grain, clover grass and whey

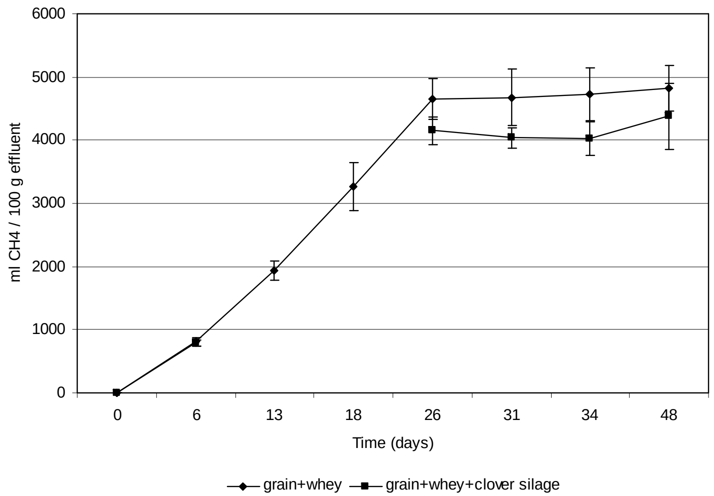


Bioethanol and biogas production

The final ethanol concentrations were 29 g/l for germinated grain and whey mixture and 22 g/l for germinated grain, whey and clover silage mixture, which corresponding to 61 and 56% of theoretical yield, respectively.

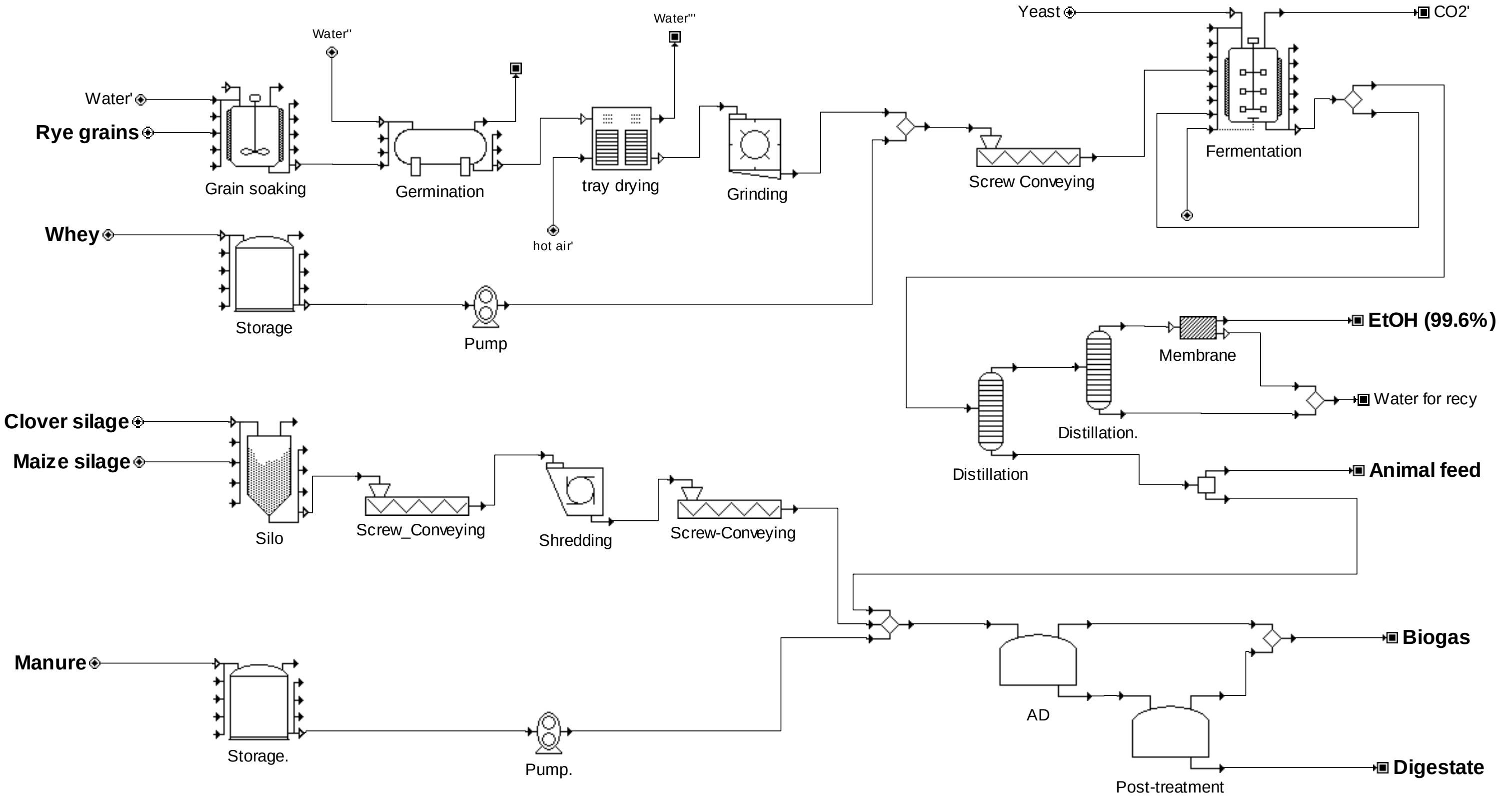


SSF on germinated grain, clover silage and whey by in situ



Biogas production on the effluent from bioethanol fermentation.

Evaluation of combined biogas and protein/bioethanol production in SuperPro Designer – 100 ha



The energy demand for a Danish organic farm (100 ha) was estimated for 180 GJ (60000 kWh)

Specification - SuperPro Designer

Roughly estimating:

- for production of ethanol: **16.2 ha of rye and 14 milking cows**
- for production of biogas: **5.7 ha clover grass silage, 2.5 ha maize silage and 13 cows**

In the presented scenario, the production of on-farm energy, in order to increase self-sufficiency of 100 ha Danish organic farm, requires around:

- **around 16 % of farm land for bioethanol**
- **around 8 % of farm land biogas**

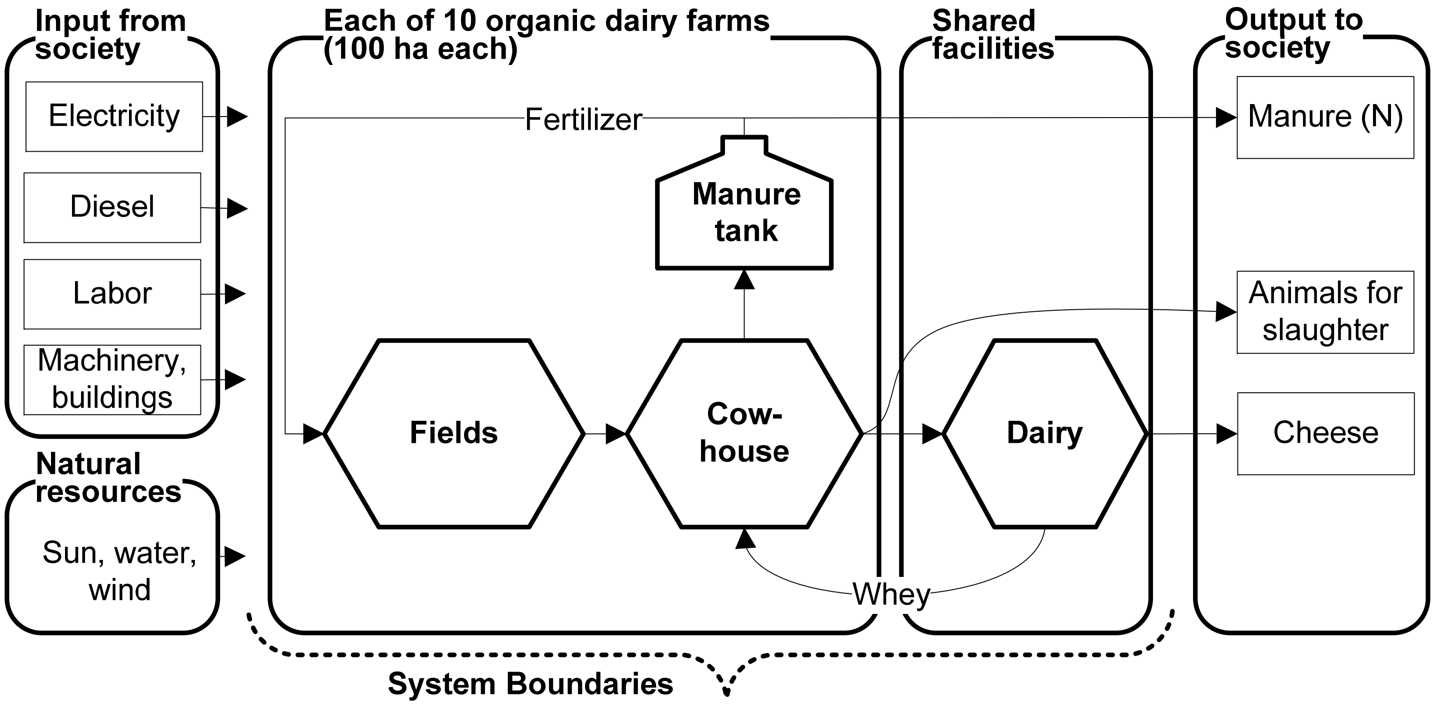
Reactors specifications

Description	Volume
Ethanol production	
Reactor working volume	1 276 L
Reactor total volume	1 418 L
Anaerobic Digestion	
Reactor working volume	30 429 L
Reactor total volume	40 572 L

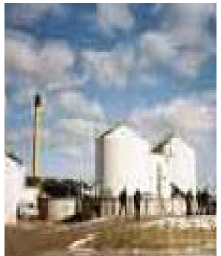
However….

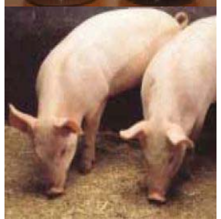
There is a question if it could be economical feasible to establish such a small on-farm bioenergy production facility or it rather would be better to build centralized biorefinery to join around 10 organic farms for the area of 1000 ha.

Material and energy flow in reference scenario – 10 x 100 ha.



Input/output of energy products in all scenarios

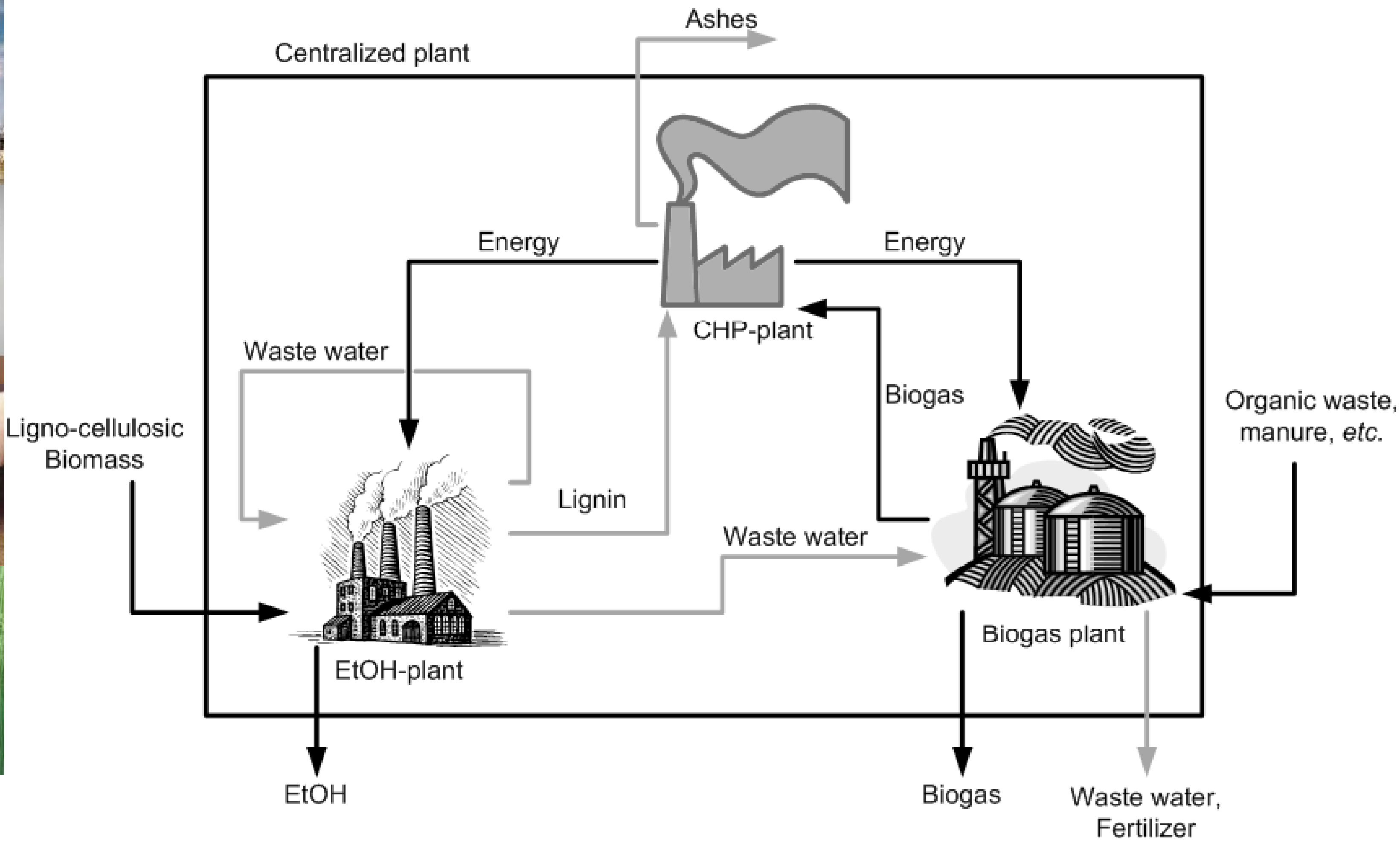





Definition of scenarios			Input/output evaluation (1000 ha^{-1})								
			Food (Person year rations of food[a])			Liquid fuels (1000 l diesel equivalents)			Electricity (TJ)		
Scenarios	Pct. of energy crops	Milk producing cows	Pro-duced	Used	Self-sufficiency[b]	Pro-duced	Used	Self-sufficiency[b]	Pro-duced	Used	Self-sufficiency[b]
1 Reference	**0%**	74	3420	20	**171**	0	59	**0**	0	4,88	**0**
2 Oilseed rape	**10%**	69	3172	20	**159**	63	62	**1,01**	0	4,55	**0**
3 Biogas	**10%**	67	3080	22	**140**	0	66	**0**	4,07	5,03	**0,81**
4 Bioethanol	**10%**	67	3080	22	**140**	123	65	**0 (1,9)**[c]	0	4,59	**0**
5 20% energy crops	**20%**	62	2850	22	**129**	63	65	**0,96**	4,07	4,70	**0,87**

[a] Based on a daily intake of 2500 kcal per person
[b] Degree of self-sufficiency. A value of 1.0 means that the system is self-sufficient.
[c] All ethanol is exported because ethanol cannot substitute diesel as a fuel. The ethanol still contains 90% water. The thermal energy content of the ethanol correspond to 1.9 times the diesel used in the system measured in J.

Conclusions
Anaerobic digestion as "waste eater"



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